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(54) PROCESS FOR DETECTING FOULING OF AN AXIAL COMPRESSOR

VORRICHTUNG ZUR VERKRUSTUNGSDETEKTION EINES AXIALVERDICHTERS.

PROCEDE DE DETECTION DE L'ENCRASSEMENT D'UN COMPRESSEUR AXIAL

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- **MATHIOUDAKIS: "Fast Response Wall Pressure Measurement as a Means of Gas Turbine Blade Fault Identification" THE AMERICAN SOCIETY OFMECHANICAL ENGINEERS, PAPER 90-GT-341, 11 - 14 June 1990, NEW YORK, pages 1-8, XP002058444**

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to a process and a device for detecting fouling of an axial compressor, said compressor comprising a rotor and a housing, said rotor being rotatably mounted within said housing for rotation about a rotational axis with variable or constant rotational speed, said compressor further comprising at least one compressor stage, each of said at least one stages comprising a row of rotor blades mounted on said rotor and being arranged one following the other in a circumferential direction with respect to said rotational axis and of a row of stator blades mounted on said housing and being arranged one following the other in a circumferential direction with respect to said rotational axis.

[0002] The invention provides for a detection of fouling of either multi- or single stage compressors. The compressor may be operated as an isolated unit or in conjunction with a power turbine engine, as would be the case in a power plant operation. The compressor may further be part of a gas turbine used for driving aeroplanes, ships or large vehicles.

BACKGROUND OF THE INVENTION

[0003] Compressors exist of a series of rotating or stationary blade rows in which the combination of a rotor (circular rotating blade row) and a stator (circular stationary blade row) forms one stage. Inside the rotor, kinetic energy is transferred to the gas flow (usually air) by the individual airfoil blades. In the following stator, this energy is manifested as a pressure rise in the gaseous air as a consequence of deceleration of the gaseous air flow. This deceleration of the gaseous air flow is induced as a result of the design of the stator section. The pressure ratio (exit pressure/ inlet pressure) of a single stage is limited because of intrinsic aerodynamic factors, so several stages are connected together in many turbo compressors to achieve higher pressure ratios than could be achieved by a single stage.

[0004] When operating an axial compressor, the problem of "fouling" arises, namely the continuous contamination of the surfaces of the rotor and stator blades with oil and dust,particularly of the first compressor stages at the inlet of the compressor.

[0005] In an initial phase of the fouling problem, an increased surface roughness of the blades may be observed, influencing the behavior of the boundary layer air associated with the blades. The air fluid flow around each blade has an associated flow boundary layer which covers each blade and coheres to the blade. The flow boundary layer associated with a rotor blade will rotate as an associated entity of the blade as the blade itself rotates. At the downstream edge of each blade, this flow boundary layer melds into an associated flow boundary entity known as the "wake or delve region" which is characterized by a localized reduction in both pressure and flow velocity. As in the case of the flow boundary layer, the associated wake region rotates with its rotor blade. As the contamination collects on the blade over a period of time, the resultant surface roughness also increases, which causes the thickness of the flow boundary layer also to increase. As a result, the wake region becomes more and more extensive and pronounced. Therefore, increasing thickness of the boundary layer will produce higher losses of the total pressure throughout the bladings, leading to efficiency reduction of the compressor.

[0006] Axial compressors therefore are "washed" after certain operation intervals by cleaning the blades of at least the front stages.

[0007] The time interval between successive cleaning operation should not be too long, as otherwise the compressor is operated with too much reduced efficiency. Under certain circumstances, the danger of compressor stall or compressor surge increases. Due to the reduced efficiency, the compressor load has to be increased (operating point moves closer to stability line) to maintain the outlet pressure.

[0008] On the other hand, it is quite uneconomical when the compressor is cleaned after a relatively short operation period, particularly as the cleaning leads to a distinct operational interruption.

[0009] Therefore, it is desirable to measure the actual fouling state of the compressor, in order to determine the optimum time for said "washing".

[0010] Contemporary turbo engines are usually equipped with fuel or energy control systems which measure and output a variety of operating parameters for the overall engine. Included in such control systems are highly accurate pressure sensing devices or systems. For example, pressure measuring systems are described in US Patent No. 4,322,977 entitled "Pressure Measuring System" filed May 27, 1980 in the names of Robert C. Sell, et al.; US Patent No. 4, 434,664 issued March 6, 1984, entitled "Pressure Ratio Measurement System", in the names of Frank J. Antonazzi, et al.; US Patent No. 4,422,335 issued December 27, 1983, entitled "Pressure Transducer" to Ohnesorge, et al.; US Patent No. 4,449,409, issued May 22, 1984, entitled "Pressure Measurement System With A Constant Settlement Time", in the name of Frank J. Antonazzi; US Patent No. 4,457,179, issued July 3, 1984, entitled "Differential Pressure Measuring System", in the names of Frank J. Antonazzi, et al.; and US Patent No. 4,422,125, issued December 20, 1983, entitled "Pressure Transducer With An Invariable Reference Capacitor", in the names of Frank J. Antonazzi, et al.

[0011] While a wide variety of pressure measuring devices can be used in conjunction with the present invention, the disclosures of the above-identified patents and the article mentioned next are hereby expressly incorporated by reference herein for a full and complete understanding of the operation of the invention.

[0012] As initially mentioned, the efficiency of said axial compressor depends on the fouling state thereof. On line derivation of the efficiency of said compressor, however, is only an indirect indicator of the fouling status and cannot be used to derive direct conclusions concerning the state of fouling; there also are many other parameters influencing the characteristics of the flowing air in the high pressure stages of said compressor and the efficiency of those stages, and those other parameters are difficult to measure.

[0013] The article "Fast Response Wall Pressure Measurement as a Means of Gas Turbine Blade Fault Identification" by K. Mathioudakis et al as presented at the "Gas Turbine and Aeroengine Congress and Exposition" from June 11-19, 1990, Brussels, Belgium, ASME Paper No. 90-GT-341, relates to the identification of blade faults. For simulating fouling of the rotor, all blades of one rotor of the compressor were coated with a textured paint, said paint layer roughening the surface and causing a slight alteration of the contour of the blades. The dynamic pressure field around the rotor was measured by fast response pressure transducers at the inner circumferential surface of the rotor housing. From the time depending pressure sensor signals, respective frequency signals (power spectra) were derived and compared with respective frequency signals of an intact compressor (without blade painting). Respective tests were performed for other blade faults, as there are bended or twisted blades, rotors with only two faulty blades (simulated by painting only these two blades). The latter faults could be more or less clearly identified from comparison of the respective power spectra. To this aim, certain indices were derived from the power spectra to be compared, namely the ratio of spectra amplitudes and the logarithm thereof. These tests show that a discrimination of the mentioned test faults is principally possible, for which complex simulation- calculations have to be performed.

[0014] This article does not deal with the problem of an actual determination of one blade fault, namely of blade fouling. The experimental setup with painting of all rotor blades is only a rough simulation of the actual fouling process, which is characterized by a more subtle increase of surface roughness of the blades during the operation time of the compressor.

SUMMARY OF THE INVENTION

[0015] It is an object of the present invention to provide a process for detecting fouling of an axial compressor which allows the monitoring of fouling.

[0016] It is a further object of this invention to provide a process for detecting fouling of an axial compressor which allows the determination of an optimum time for "washing".

[0017] Another object of the invention is to provide a process for detecting fouling of an axial compressor allowing an online monitoring, using common calculation techniques for the signal evaluation.

[0018] One or more of these objects are solved by the process according to the invention, said process comprising the following steps:

a) measuring of pressure fluctuations within at least one of said compressor stages in the region of said housing by means of at least one pressure sensing device, each pressure sensing device delivering a sensor signal, respectively;

b) deriving a frequency signal from each of said sensor signals, said frequency signal comprising a set of a plurality of frequency components of each of said respective sensor signals in a respective frequency interval wherein each frequency signal is indicative of the amplitudes of each of the frequency components of said respective sensor signals within the respective frequency interval;

c) checking whether at least one frequency component in at least one of said frequency signals further comprises a characteristic peak in a region of a characteristic frequency assigned to one of said compressor stages, said characteristic frequency being defined as the product of said rotational speed and the number of the rotor blades of the respective compressor stage;

d) deriving a fouling parameter from said frequency signal, said fouling parameter depending on a peak parameter, said peak parameter being indicative of the form of said characteristic peak.

[0019] According to the invention, the characteristic peak is observed. This peak is sensitive for changes in the flow conditions. When the compressor is operating, the wake regions of the rotating blades, passing the pressure sensing device, produce a pressure variation at the pressure sensing device with the characteristic frequency. The frequency signal derived from the respective sensor signal shows a respective characteristic peak, the form of which is defined by respective peak parameters (peak height, peak width or the like). It was found that with increasing fouling of the rotor stage, the respective characteristic peak becomes more distinct (increasing height and width) which may be attributed to the wake regions increasing with fouling. Only one single parameter, that is the fouling parameter, has to be calculated and monitored.

[0020] The pressure fluctuations due to the wake regions of the rotating blades can be measured best by said pressure sensing device being arranged at said housing between the rotor blades and the stator blades of the respective compressor stage.

[0021] It is preferred that the at least one pressure sensing device be located near the low pressure end of said axial compressor. The pressure sensing device thus is most sensitive for the first compressor stages which primarily are subject to fouling. Principally, the characteristic peak of, for example, the first stage, may

also be measured at another stage if the characteristic frequencies are different; however, the peak amplitude measured will be lower.

[0022] For the process according to the invention, only the time varying part of the absolute pressure is of interest. These pressure fluctuations may be directly measured by means of a piezoelectric or piezoresistive pressure sensor, especially a piezocapacitive pressure sensor. Another less preferred pressure sensing device is a strain gauge pressure sensor.

[0023] The frequency signal may easily be derived from the detector signals by using common evaluation techniques, for example fast Fourier transformation (FFT) or fast Hartley transformation (FHT). No model calculations are necessary. The respective electronic transformation units are readily obtainable.

[0024] The peak parameter indicative of the form of the characteristic peak may be the peak height or the peak width. In both cases, the parameter is easy to determine and easy to be compared with a limit value or with the limits of an allowed region.

[0025] In order to enhance the accuracy and/or to reduce the evaluation efforts, the frequency interval in which the frequency signal has to be evaluated, is determined to have a reduced width of less than 4000 Hz. A preferred width is 2000 Hz so that the frequency signal has to be evaluated only between the characteristic frequency minus 1000 Hz and the characteristic frequency plus 1000 Hz.

[0026] In order to enhance the reliability of the fouling detection according to the invention, it is proposed to divide the parameter of the characteristic peak by an operating parameter indicative of the operating condition of said compressor, this quotient defining the fouling parameter. The peak parameter not only depends on the fouling status of the compressor, but also on the respective operating condition of the compressor. In essential, the fouling parameter, as defined, is independent of the operating condition of the compressor.

[0027] The choice of the operating parameter depends on the kind of control of the axial compressor. In case ofT44- control (constant air temperature at a certain point of the compressor turbine entity, namely the low pressure turbine inlet), it is preferred to use the measured power output of the compressor as operating parameter.

[0028] In a preferred embodiment of the invention, a status change signal indicative of a change of the operational status of the compressor, is generated in case of said fouling parameter having a value lying beyond a determined value range.

[0029] An alternative embodiment of the invention solving one or more of the above mentioned objects, comprises the following steps:

a) measuring of pressure fluctuations within at least one of said compressor stages in the region of said housing by means of at least one pressure sensing device, each pressure sensing device delivering a sensor signal, respectively;

b) deriving a frequency signal from each of said sensor signals, said frequency signal comprising a set of a plurality of frequency components of each of said respective sensor signals in a respective frequency interval wherein each frequency signal is indicative of the amplitudes of each of the frequency components of said respective sensor signals within the respective frequency interval;

c) deriving a fouling parameter from said frequency signal, said fouling parameter depending on an integral value of said frequency signal, said integral value being defined as an integral of said frequency signal over a predetermined frequency interval.

[0030] It was found that not only the characteristic peak, but also the whole frequency spectrum is influenced by compressor fouling. This phenomenon supposedly is due to the flow perturbation in the stages successive to that stage with blade fouling. The perturbed successive stages in turn disturb the flow conditions of the preceding stages so that the noise level of the frequency spectrum, measured at, for example the first stage, is respectively increased. The integral value of the frequency signal is obtained by simple calculation. The monitoring of fouling may be performed easily, since only one single parameter, namely the fouling parameter, is to be observed.

[0031] It is preferred that the frequency interval equals the integration interval. Thus, the whole frequency spectrum is taken into consideration.

[0032] In order to compensate for changing operating conditions, the fouling parameter may be defined as the integral value divided by an operating parameter. Preferably, said operating parameter is indicative of the power output of the compressor.

[0033] The invention further relates to a device for detecting fouling of an axial compressor in accordance with the above described process for detecting fouling of an axial compressor by determining at least one peak parameter signal indicative of the form of a characteristic peak. The invention also relates to a device for detecting fouling of an axial compressor in accordance with the above described process, determining an integral value signal by integrating the frequency signal over a predetermined frequency interval.

BRIEF DESCRIPTION OF THE DRAWINGS

[0034] For a better understanding of the invention, reference is made to the following description and the drawings.

Figure 1 is a simplified graphic representation of an axial compressor as part of a gas turbine showing the location of a dynamic pressure probe;

Figure 2 is a schematic representation of the compressor of Figure 1 illustrating the first compressor stage at the low pressure end of the compressor;

Figure 3 is a block diagram of the dynamic pressure probe connected to an evaluation unit;

Figure 4 illustrates a frequency signal with a characteristic peak;

Figures 5a,b,c, show three successive forms of the characteristic peak of Figure 4 obtained with increasing fouling, starting with Figure 5a;

Figure 6 shows the development of the amplitude of the characteristic peak as a function of the compressor running time;

Figure 7 shows the shift of the frequency signal with fouling;

Figure 8 shows the development of the integral value of the frequency signal divided by the power output of the compressor as a function of the compressor running time.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0035] Referring to the drawings, wherein equal numerals correspond to equal elements throughout, first reference is made to Figures 1 and 2 wherein a typical compressor part of a gas turbine engine is depicted (including the present invention). The compressor 10 is comprised of a low pressure part 12 and a high pressure part 14. Rotor blades 16 of the compressor are mounted on a shaft 18 of a rotor 20. Stator blades 22 (guide vanes) are mounted in a housing (casing) 24 of said compressor 10 and are therefore stationary. Air enters at an inlet 26 of the gas turbine engine and is transported axially to following compressor stages of the compressor under increasing pressure to an outlet 28. An axis 30 of said compressor is defined as the axis of rotation of the rotor 20.

[0036] Each of the mentioned compressor stages consists of two rows of blades with equal blade number, namely a row of rotor blades 16 and a row of stator blades 22. The blades of each row are arranged one following the other in a circumferential direction with respect to said axis 30. Figure 2 shows the first compressor stage of the compressor at its inlet 26 (low pressure axial end of the compressor) with rotor blades 16 and stator blades 22. The compressor 10, according to Figure 1, comprises an accessory gear box 30 enabling the adjustment of orientation of blades in order to change the load of the respective stages. Figure 1 further shows a bleed air collector 31 between the low pressure part 12 and the high pressure part 14. As the compressor, used in connection with the invention, is of common construction, it is not necessary to go into further detail.

[0037] According to the invention, a pressure sensing device in form of a dynamic pressure sensor 32 is mounted in the axial gap between the rotor blades 16 and the stator blades 22 of the first stage in the low pressure part of the compressor 10 nearest to the inlet 26 of compressor 10. An inlet opening 35 of the sensor 32 is flush with an inner circumferential surface 34 of a wall 36 defining said housing 24. Thus, sensor 32 measures the pressure fluctuations of the first stage, occurring at the inner circumferential face 34. Since the sensor 32 is located in the region of the axial gap between the row of rotor blades 16 and stator blades 22, following the rotor blades downstream, the sensor 32 is sensitive for the so called wake regions (Dellenregionen) being developed by the axial air flow at the downstream edge 38 of each rotary blade. These wake regions rotating with the respective rotary blade 16, are regions with lower density and flow velocity and with varying flow direction.

[0038] Instead of directly mounting the sensor 32 in an opening 40 (borescope hole), it is also possible to use an elongated adaptor (not shown) which, with one of its ends, is mounted to the opening 40 and, at its other end, carries the sensor.

[0039] The illustrated location of the sensor 32 at the low pressure axial end of the low pressure part 12 of the compressor 10 is preferred, because the amount of fouling occurring during the operational time of an axial compressor in a stage near the inlet 26 of the compressor 10, is higher than the amount of fouling in stages downstream of the first stage. Further, the disturbance of the pressure fluctuations, used for determining the amount of fouling of a compressor, which are caused by pressure fluctuations in other stages, show the least influence on the characteristic peak (described later on) of the pressure signal detected in the stages near the inlet 26. Although not illustrated, further pressure sensors may be located in stages following the first stage downstream to obtain additional information about the amount of fouling in these other stages. Dynamic pressure sensors, preferably piezoelectric pressure sensors, are used because of their reliability, high temperature operability and sensitivity for high frequency pressure fluctuations up to 20 000 Hz (for example Kistler Pressure Sensor, Type 6031).

[0040] As shown in Figures 2 and 3, the sensor is provided with an amplifier 42, amplifying the respective sensor signal. The amplifier 42 is connected via lines 44, 46 to an evaluation unit 48.

[0041] As shown in Figure 3, the evaluation unit 48 contains a fast Fourier transformer (FFT) analyzer 50 which receives signals from amplifier 42 through an an-

alog digital converter ADC (or multiplexer) 52 which is connected between the amplifier 42 and the FFT analyzer 50.

[0042] The signals from the FFT analyzer are transmitted to a computer unit 54, comprising several subunits, amongst them a contamination detector 56. Besides this contamination detector 56, further detectors for the status of the compressor may be installed, for example a stall detector 58 for monitoring the operational status of the compressor 10 and a blade excitation detector 60 for detecting pressure fluctuations which are able to induce high amplitude blade vibrations, which may damage the compressor. However, the fouling detection according to the present invention, may also be performed independently of stall detection and blade excitation detection.

[0043] In order to facilitate the computing of the frequency signals output from the FFT analyzer 50, a unit 62 for signal preparation may be connected between the FFT- analyzer 50 and the detectors 56, 58, 60. The unit 62 contains filter algorithms for handling and smoothing digital data as received from the FFT analyzer. The resulting frequency signals from the FFT analyzer, after smoothing via unit 62, are forwarded to said detectors 56, 58, 60 for comparison with respective reference patterns. If the comparison analyzers indicate deviations beyond a predetermined allowable threshold of difference, the computed evaluation is transmitted to a status indicating unit 64 to indicate contamination or stall or blade excitation. Thus, the operation and status of compressor 10 can be monitored.

[0044] In detectors 56, 58 60, the smoothed frequency signal is evaluated, said frequency signal being indicative of the amplitudes of frequency components of the respective sensor signal in a respective frequency interval. The contamination detector 56 examines the frequency signals in a specific frequency region around a specific frequency, the so called characteristic frequency $_C$, said characteristic frequency $_C$ being defined as the product of the present rotational speed n of rotor 20 and the blade number z of the rotor blades of the respective compressor stage:

$$C = n * z$$

[0045] The frequency interval around $_C$ may have a width of less than 4000 Hz and preferably is 2000 Hz, so that the upper limit $_{UL}$ may be $_C$ + 1000 Hz and the lower limit $_{LL}$ may be $_C$ - 1000 Hz (see Figure 5). In general, the blade number of rotor blades equals the blade number of stator blades within the same stage.

[0046] The wake regions, rotating with rotor blades 16 of the respective compressor stage, are passing the sensor 32 with the characteristic frequency $_C$. Therefore, the frequency signal shows a respective characteristic peak 70 at $_C$. It was found that the form of the characteristic peak varies in a characteristic manner if fouling of the respective stage increases, starting from a point after cleaning of the compressor. The peak becomes more characteristic as shown in Figure 5b (peak 70b). Both, the peak height and the peak width increase. This behavior is due to an increase of the wake regions (Dellenregionen) of the rotating blades, producing more characteristic pressure variations with the characteristic frequency at the location of sensor 32.

[0047] A further increase of fouling leads to a further increase of the characteristic peak in height and width (peak 70c in Fig. 5c). Thus, the observation of the characteristic peak is a sensitive tool for detecting the amount of fouling of a respective compressor stage. One possibility of detecting changes of the form of the characteristic peak 70 would be a comparison of a predetermined peak form by means of pattern recognition. However, the evaluation is simplified, if not the complete peak form, but only one peak parameter, is observed and compared with limit values. This peak parameter may be defined as peak height a_{max} above the background line 72 or the peak width $_{2-1}$ as shown in Fig. 4.

[0048] Figure 6 shows the development of the amplitude of a characteristic peak as a function of the compressor running time. In this diagram, a first variation range 74 is determined. When the amplitude of the characteristic peak lies within said range 74, the compressor is defined clean. Beginning with the time after the compressor has been cleaned, an increase of the amplitude of the characteristic peak is to be observed, whereby the amplitudes of said characteristic peak, measured at respective times, lie within an inclined variation band 76 within a second variation range 77. If, with continuous compressor running time, a third range 78 is reached, the compressor condition is rated contaminated. This state does not allow an efficient compressor operation and the compressor has to be cleaned. After cleaning (dashed line 79), the amplitude of the characteristic peak again lies within the first variation range 74.

[0049] With increasing compressor running time, it is also observed that, besides the above mentioned variation of the form of the characteristic peak, the noise level of the complete frequency signal is shifted to higher values. In Figure 7 a first frequency signal 80 is depicted (dashed curve), obtained after cleaning the compressor. This signal 80 shows characteristic peaks 84, 86, 88 above a certain base line 81, representing the frequency dependent noise components of the frequency signal. The characteristic peaks correspond to different stages (with different blade numbers). Figure 7 further shows a second frequency signal 82, obtained from the same pressure sensing device as in case of signal 80, but after running of the compressor for a certain running time after washing. Signal 82 is shifted upwards, relative to signal 80, maintaining its general form.

[0050] This shift is due to an overall increase of the frequency dependent noise components of the frequency signal. This shift may be calculated as the difference (area D in Fig. 7) of respective integral values of the sig-

nals 80 and 82, where the integral value is defined as the integral of the respective frequency signal over the entire frequency interval of this signal. The difference between the integral value of the frequency signal 80 and the integral value of the frequency signal 82, thus enables to determine the fouling condition of the compressor.

[0051] In case that with continuous compressor running time the integral value reaches a threshold corresponding to the third range 78 in Fig. 6, the compressor condition is rated as contaminated and the compressor has to be cleaned in order to allow an efficient operation thereof.

[0052] However, the value of the integral, calculated during compressor operation, further depends on the operational condition of the compressor. Thus, for being able to determine the fouling condition of the compressor, independent of the operational condition thereof, the integral value has to be related to an operating parameter of said compressor. Said operating parameter is indicative of the operating condition of the compressor and may, for example, be the power output of said compressor.

[0053] In Figure 8, the integral value, related to the power output of the compressor, is shown as a function of the compressor running time. Setting out from a time after having cleaned the compressor, the curve 84 firstly shows a relatively constant integral value, divided by the power output of the compressor. With increasing compressor running time (here after 30 days), a distinct increase of this quotient is to be observed, thus indicating an increasing amount of fouling of the compressor. According to the third range 78 in Fig. 6, a threshold value may be set (for example 280 in the arbitrary units of this diagram). After exceeding this value, in order to obtain an efficient operation of the compressor, at least the most contaminated stages of the compressor have to be cleaned.

[0054] Thus, the observation of the development of the characteristic peak or/and the development of the integral value, give a sensitive tool for determining the fouling condition of the compressor. By comparing these parameters to the operational status, an observation independent of the operational status can be achieved.

Claims

1. Process for detecting fouling of an axial compressor, said compressor comprising a rotor and a housing, said rotor being rotatably mounted within said housing for rotation about a rotational axis with variable or constant rotational speed, said compressor further comprising at least one compressor stage, each of said at least one compressor stages comprising a row of rotor blades mounted on said rotor and being arranged one following the other in a circumferential direction with respect to said rotational axis and of a row of stator blades mounted on said housing and being arranged one following the other in a circumferential direction with respect to said rotational axis, said process comprising the following steps:

   a) measuring of pressure fluctuations within at least one of said compressor stages in the region of said housing by means of at least one pressure sensing device, each pressure sensing device delivering a sensor signal, respectively;
   b) deriving a frequency signal from each of said sensor signals, said frequency signal comprising a set of a plurality of frequency components of each of said respective sensor signals in a respective frequency interval wherein each frequency signal is indicative of the amplitudes of each of the frequency components of said respective sensor signals within the respective frequency interval;
   c) checking whether at least one frequency component in at least one of said frequency signals further comprises a characteristic peak in a region of a characteristic frequency assigned to one of said compressor stages, said characteristic frequency being defined as the product of said rotational speed and the number of the rotor blades of the respective compressor stage;
   d) deriving a fouling parameter from said frequency signal, said fouling parameter depending on a peak parameter, said peak parameter being indicative of the form of said characteristic peak.

2. Process according to claim 1, wherein said pressure sensing device is arranged at said housing between the rotor blades and the stator blades of one of said compressor stages.

3. Process according to claim 1, wherein said at least one pressure sensing device is located near the low pressure end of said axial compressor.

4. Process according to claim 1, wherein said pressure sensing device comprises a piezoelectric or piezoresistive pressure sensor.

5. Process according to claim 1, wherein said frequency signal is obtained by fast Fourier transformation (FFT).

6. Process according to claim 1, wherein said frequency signal is obtained by fast Hartley transformation (FHT).

7. Process according to claim 1, wherein said peak pa-

rameter is indicative of the peak height of the characteristic peak.

8. Process according to claim 7, wherein the peak height is defined as the ratio of a difference of a maximum value of the set of frequency components of a frequency signal in the region of said characteristic frequency and a mean value of said set of frequency components within a predetermined frequency range about said characteristic frequency to said mean value.

9. Process according to claim 1, wherein said peak parameter is indicative of a peak width of said characteristic peak.

10. Process according to claim 9, wherein said peak width is defined as full width at half maximum.

11. Process according to claim 1, wherein said predetermined frequency interval has a width of less than 4000 Hz.

12. Process according to claim 11, wherein said peak frequency interval has a width of 2000 Hz.

13. Process according to claim 1, wherein said fouling parameter is defined as the peak parameter of the characteristic peak divided by an operating parameter indicative of the operating condition of said compressor.

14. Process according to claim 13, wherein said operating parameter is indicative of the power output of the compressor.

15. Process according to claim 1, wherein a status change signal indicative of a change of operational status of said compressor is generated in case of said fouling parameter having a value lying beyond a predetermined value range.

16. Process for detecting fouling of an axial compressor, said compressor comprising a rotor and a housing, said rotor being rotatably mounted within said housing for rotation about a rotational axis with variable or constant rotational speed, said compressor further comprising at least one compressor stage, each of said at least one compressor stages comprising a row of rotor blades mounted on said rotor and being arranged one following the other in a circumferential direction with respect to said rotational axis and of a row of stator blades mounted on said housing and being arranged one following the other in a circumferential direction with respect to said rotational axis, said process comprising the following steps:

a) measuring of pressure fluctuations within at least one of said compressor stages in the region of said housing by means of at least one pressure sensing device, each pressure sensing device delivering a sensor signal, respectively;

b) deriving a frequency signal from each of said sensor signals, said frequency signal comprising a set of a plurality of frequency components of each of said respective sensor signals in a respective frequency interval wherein each frequency signal is indicative of the amplitudes of each of the frequency components of said respective sensor signals within the respective frequency interval;

c) deriving a fouling parameter from said frequency signal, said fouling parameter depending on an integral value of said frequency signal, said integral value being defined as an integral of said frequency signal over a predetermined frequency interval.

17. Process according to claim 16, wherein said pressure sensing device is arranged at said housing between the rotor blades and the stator blades of one of said compressor stages.

18. Process according to claim 16, wherein said at least one pressure sensing device is located near the low pressure end of said axial compressor.

19. Process according to claim 16, wherein said pressure sensing device comprises a piezoelectric or piezoresistive pressure sensor.

20. Process according to claim 16, wherein said frequency signal is obtained by fast Fourier transformation (FFT).

21. Process according to claim 16, wherein said frequency signal is obtained by fast Hartley transformation (FHT).

22. Process according to claim 16, wherein said integration interval is 0 to 20 000 Hz.

23. Process according to claim 16, wherein said frequency interval equals said integration interval.

24. Process according to claim 16, wherein said fouling parameter is defined as the integral value divided by an operating parameter indicative of the operating condition.

25. Process according to claim 24, wherein said operating parameter is indicative of the power output of the compressor.

26. Process according to claim 16, wherein a status change signal indicative of a change of operational status of said compressor is generated in case of said fouling parameter having a value lying beyond a determined value range.

27. Device for detecting fouling of an axial compressor said compressor comprising a rotor and a housing, said rotor being rotatably mounted within said housing for rotation about a rotational axis with variable or constant rotational speed, said compressor further comprising at least one compressor stage, each of said at least one compressor stages comprising a row of rotor blades mounted on said rotor and being arranged one following the other in a circumferential direction with respect to said rotational axis and of a row of stator blades mounted on said housing and being arranged one following the other in a circumferential direction with respect to said rotational axis, said device comprising at least one pressure sensing device for measuring of pressure fluctuations within at least one of said compressor stages in the region of said housing by means of at least one pressure sensing device, each pressure sensing device delivering a sensor signal, respectively, at least one transformation unit for deriving a frequency signal from each of said sensor signals, said frequency signal comprising a set of a plurality of frequency components of each of said respective sensor signals in a respective frequency interval wherein each frequency signal is indicative of the amplitudes of each of the frequency components of said respective sensor signals within the respective frequency interval, a peak evaluation unit being adapted for checking whether at least one frequency component in at least one of said frequency signals further comprises a characteristic peak in a region of a characteristic frequency assigned to one of said compressor stages, said characteristic frequency being defined as the product of said rotational speed and the number of the rotor blades of the respective compressor stage, a fouling parameter deriving unit for deriving a fouling parameter from said frequency signal, said fouling parameter depending on a peak parameter, said peak parameter being indicative of the form of said characteristic peak.

28. Device according to claim 27, wherein said pressure sensing device is arranged at said housing between the rotor blades and the stator blades of one of said compressor stages.

29. Device according to claim 27, wherein said pressure sensing device comprises a piezoelectric or piezoresistive pressure sensor.

30. Device according to claim 27, wherein said at least one pressure sensing device is located near the low pressure end of said axial compressor.

31. Device according to claim 27, wherein said transformation unit comprises a fast Fourier transformation unit.

32. Device according to claim 27, wherein said transformation unit comprises a fast Hartley transformation unit (FHT).

33. Device according to claim 27, wherein a status indicating unit is provided for receiving said fouling parameter signal and being indicative thereof.

34. Device for detecting fouling of an axial compressor said compressor comprising a rotor and a housing, said rotor being rotatably mounted within said housing for rotation about a rotational axis with variable or constant rotational speed, said compressor further comprising at least one compressor stage, each of said at least one compressor stages comprising a row of rotor blades mounted on said rotor and being arranged one following the other in a circumferential direction with respect to said rotational axis and of a row of stator blades mounted on said housing and being arranged one following the other in a circumferential direction with respect to said rotational axis, said device comprising at least one pressure sensing device for measuring of pressure fluctuations within at least one of said compressor stages in the region of said housing by means of at least one pressure sensing device, each pressure sensing device delivering a sensor signal, respectively, at least one transformation unit for deriving a frequency signal from each of said sensor signals, said frequency signal comprising a set of a plurality of frequency components of each of said respective sensor signals in a respective frequency interval wherein each frequency signal is indicative of the amplitudes of each of the frequency components of said respective sensor signals within the respective frequency interval, an integrating unit for integrating said frequency signal over a predetermined frequency interval and outputting an integral value signal, a fouling parameter deriving unit for deriving a fouling parameter signal from said integral value signal.

35. Device according to claim 34, wherein said pressure sensing device is arranged at said housing between the rotor blades and the stator blades of one of said compressor stages.

36. Device according to claim 34, wherein said pressure sensing device comprises a piezoelectric or piezoresistive pressure sensor.

37. Device according to claim 34, wherein said at least one pressure sensing device is located near the low pressure end of said axial compressor.

38. Device according to claim 34, wherein said transformation unit comprises a fast Fourier transformation unit.

39. Device according to claim 34, wherein said transformation unit comprises a fast Hartley transformation unit (FHT).

40. Device according to claim 34, wherein a status indicating unit is provided for receiving said fouling parameter signal and being indicative thereof.

Patentansprüche

1. Verfahren zum Erfassen einer Verschmutzung eines Axialverdichters, wobei der Verdichter einen Rotor und ein Gehäuse umfaßt, wobei der Rotor drehbar in dem Gehäuse zum Drehen um eine Drehachse mit variabler oder konstanter Drehgeschwindigkeit angebracht ist, wobei der Verdichter ferner wenigstens eine Verdichterstufe umfaßt, wobei jede der wenigstens einen Verdichterstufe eine Reihe von am Rotor angebrachten und aufeinanderfolgend in Umfangsrichtung bezüglich der Drehachse angeordneten Rotorschaufeln und eine Reihe von am Gehäuse angebrachten und aufeinanderfolgend in einer Umfangsrichtung bezüglich der Drehachse angeordneten Statorschaufeln aufweist, wobei das Verfahren die folgenden Schritte umfaßt:

a) Messen von Druckschwankungen innerhalb wenigstens einer der Verdichterstufen im Bereich des Gehäuses mittels wenigstens einer Drucksensiervorrichtung, wobei jede Drucksensiervorrichtung jeweils ein Sensorsignal ausgibt;
b) Ableiten eines Frequenzsignals von jedem der Sensorsignale, wobei das Frequenzsignal eine Gruppe einer Mehrzahl von Frequenzkomponenten von jedem der jeweiligen Sensorsignale in einem jeweiligen Frequenzintervall umfaßt, wobei jedes Frequenzsignal die Amplituden jeder der Frequenzkomponenten der jeweiligen Sensorsignale innerhalb des jeweiligen Frequenzintervalls angibt;
c) Überprüfen, ob wenigstens eine Frequenzkomponente in wenigstens einem der Frequenzsignale ferner eine charakteristische Spitze in einem Bereich einer charakteristischen Frequenz umfaßt, welche einer der Verdichterstufen zugeordnet ist, wobei die charakteristische Frequenz als das Produkt der Drehzahl und der Anzahl von Rotorschaufeln der jeweiligen Verdichterstufe definiert ist;
d) Ableiten eines Verschmutzungsparameters vom Frequenzsignal, wobei der Verschmutzungsparameter von einem Spitzenparameter abhängt, wobei der Spitzenparameter die Gestalt der charakteristischen Spitze angibt.

2. Verfahren nach Anspruch 1, wobei die Drucksensiervorrichtung am Gehäuse zwischen den Rotorschaufeln und den Statorschaufeln von einer der Verdichterstufen angeordnet ist.

3. Verfahren nach Anspruch 1, wobei die wenigstens eine Drucksensiervorrichtung nahe dem Niederdruckende des Axialverdichters angeordnet ist.

4. Verfahren nach Anspruch 1, wobei die Drucksensiervorrichtung einen piezoelektrischen oder piezoresistiven Drucksensor umfaßt.

5. Verfahren nach Anspruch 1, wobei das Frequenzsignal durch eine schnelle Fourier-Transformation (FFT) erhalten wird.

6. Verfahren nach Anspruch 1, wobei das Frequenzsignal durch eine schnelle Hartley-Transformation (FHT) erhalten wird.

7. Verfahren nach Anspruch 1, wobei der Spitzenparameter die Spitzenhöhe der charakteristischen Spitze angibt.

8. Verfahren nach Anspruch 7, wobei die Spitzenhöhe als das Verhältnis einer Differenz eines Maximalwerts der Gruppe von Frequenzkomponenten eines Frequenzsignals im Bereich der charakteristischen Frequenz und eines Mittelwerts der Gruppe von Frequenzkomponenten innerhalb eines vorbestimmten Frequenzbereichs um die charakteristische Frequenz zum Mittelwert ist.

9. Verfahren nach Anspruch 1, wobei der Spitzenparameter die Spitzenbreite der charakteristischen Spitze angibt.

10. Verfahren nach Anspruch 9, wobei die Spitzenbreite als volle Breite bei halbem Maximum definiert ist.

11. Verfahren nach Anspruch 1, wobei das vorbestimmte Frequenzintervall eine Breite von 4.000 Hz besitzt.

12. Verfahren nach Anspruch 11, wobei das Spitzenfrequenzintervall eine Breite von 2.000 Hz besitzt.

13. Verfahren nach Anspruch 1, wobei der Verschmutzungsparameter als der Spitzenparameter der cha-

rakteristischen Spitze geteilt durch einen Betriebsparameter ist, welcher den Betriebszustand des Verdichters angibt.

14. Verfahren nach Anspruch 13, wobei der Betriebsparameter die Ausgangsleistung des Verdichters angibt.

15. Verfahren nach Anspruch 1, wobei ein eine Änderung des Betriebszustands des Verdichters anzeigendes Zustandsänderungssignal erzeugt wird im Falle, daß der Verschmutzungsparameter einen Wert besitzt, welcher oberhalb eines vorbestimmten Wertebereichs liegt.

16. Verfahren zum Erfassen einer Verschmutzung eines Axialverdichters, wobei der Verdichter einen Rotor und ein Gehäuse umfaßt, wobei der Rotor drehbar innerhalb des Gehäuses zum Drehen um eine Drehachse mit variabler oder konstanter Drehgeschwindigkeit angebracht ist, wobei der Verdichter ferner wenigstens eine Verdichterstufe aufweist, wobei jede der wenigstens einen Verdichterstufe eine Reihe von am Rotor angebrachten und aufeinander folgend in einer Umfangsrichtung bezüglich der Drehachse angeordneten Rotorschaufeln und eine Reihe von am Gehäuse angebrachten und aufeinander folgend in einer Umfangsrichtung bezüglich der Drehachse angeordneten Statorschaufeln umfaßt, wobei das Verfahren die folgenden Schritte umfaßt:

a) Messen von Druckschwankungen innerhalb wenigstens einer der Verdichterstufen im Bereich des Gehäuses mittels wenigstens einer Drucksensiervorrichtung, wobei jede Drucksensiervorrichtung jeweils ein Sensorsignal ausgibt;

b) Ableiten eines Frequenzsignals von jedem der Sensorsignale, wobei das Frequenzsignal eine Gruppe einer Mehrzahl von Frequenzkomponenten von jedem der jeweiligen Sensorsignale in einem jeweiligen Frequenzintervall umfaßt, wobei jedes Frequenzsignal die Amplituden jeder der Frequenzkomponenten der jeweiligen Sensorsignale innerhalb des jeweiligen Frequenzintervalls angibt;

c) Ableiten eines Verschmutzungsparameters von dem Frequenzsignal, wobei der Verschmutzungsparameter von einem Integralwert des Frequenzsignals abhängt, wobei der Integralwert als ein Integral des Frequenzsignals über ein vorbestimmtes Frequenzintervall definiert ist.

17. Verfahren nach Anspruch 16, wobei die Drucksensiervorrichtung am Gehäuse zwischen den Rotorschaufeln und den Statorschaufeln von einer der Verdichterstufen angeordnet ist.

18. Verfahren nach Anspruch 16, wobei wenigstens eine Drucksensiervorrichtung nahe dem Niederdruckende des Axialverdichters angeordnet ist.

19. Verfahren nach Anspruch 16, wobei die Drucksensiervorrichtung einen piezoelektrischen oder einen piezoresistiven Drucksensor umfaßt.

20. Verfahren nach Anspruch 16, wobei das Frequenzsignal durch eine schnelle Fourier-Transformation (FFT) erhalten wird.

21. Verfahren nach Anspruch 16, wobei das Frequenzsignal durch eine schnelle Hartley-Transformation (FHT) erhalten wird.

22. Verfahren nach Anspruch 16, wobei das Integrationsintervall 0 bis 20.000 Hz ist.

23. Verfahren nach Anspruch 16, wobei das Frequenzintervall gleich dem Integrationsintervall ist.

24. Verfahren nach Anspruch 16, wobei der Verschmutzungsparameter als Integralwert geteilt durch einen Betriebsparameter definiert ist, welcher den Betriebszustand anzeigt.

25. Verfahren nach Anspruch 24, wobei der Betriebsparameter die Ausgangsleistung des Verdichters anzeigt.

26. Verfahren nach Anspruch 16, wobei ein eine Änderung des Betriebszustands des Verdichters anzeigendes Zustandsveränderungssignal in dem Fall erzeugt wird, in welchem der Verschmutzungsparameter einen über einem vorbestimmten Wertebereich liegenden Wert besitzt.

27. Vorrichtung zum Erfassen einer Verschmutzung eines Axialverdichters, wobei der Verdichter einen Rotor und ein Gefäuse umfaßt, wobei der Rotor drehbar innerhalb des Gehäuses zum Drehen um eine Drehachse mit variabler oder konstanter Drehgeschwindigkeit angebracht ist, wobei der Verdichter ferner wenigstens eine Verdichterstufe umfaßt, wobei jede der wenigstens einen Verdichterstufe eine Reihe von am Rotor angebrachten und aufeinander folgend in einer Umfangsrichtung bezüglich der Drehachse angeordneten Rotorschaufeln und eine Reihe von am Gehäuse angebrachten und aufeinander folgend in einer Umfangsrichtung bezüglich der Drehachse angeordneten Statorschaufeln umfaßt, wobei die Vorrichtung wenigstens eine Drucksensiervorrichtung umfaßt zum Messen von Druckschwankungen innerhalb wenigstens einer der Verdichterstufen im Bereich des Gehäuses mit-

tels wenigstens einer Drucksensiervorrichtung, wobei jede Drucksensiervorrichtung jeweils ein Sensorsignal ausgibt, wenigstens eine Transformationseinheit zum Ableiten eines Frequenzsignals von jedem der Sensorsignale, wobei das Frequenzsignal eine Gruppe einer Mehrzahl von Frequenzkomponenten von jedem der jeweiligen Sensorsignale in einem jeweiligen Frequenzintervall umfaßt, wobei jedes Frequenzsignal die Amplituden von jeder der Frequenzkomponenten der jeweiligen Sensorsignale innerhalb des jeweiligen Frequenzintervalls angibt, eine Spitzenauswerteeinheit, welche dazu ausgelegt ist, zu überprüfen, ob wenigstens eine Frequenzkomponente in wenigstens einem der Frequenzsignale ferner eine charakteristische Spitze in einem Bereich einer charakteristischen Frequenz aufweist, welche einer der Verdichterstufen zugeordnet ist, wobei die charakteristische Frequenz als das Produkt der Drehzahl und der Anzahl von Rotorschaufeln der jeweiligen Verdichterstufe definiert ist, eine Verschmutzungsparameter-Ableiteinheit zum Ableiten eines Verschmutzungsparameters vom Frequenzsignal, wobei der Verschmutzungsparameter von einem Spitzenparameter abhängt, welcher Spitzenparameter die Gestalt der charakteristischen Spitze angibt.

28. Vorrichtung nach Anspruch 27, wobei die Drucksensiervorrichtung am Gehäuse zwischen den Rotorschaufeln und den Statorschaufeln von einer der Verdichterstufen angeordnet ist.

29. Vorrichtung nach Anspruch 27, wobei die Drucksensiervorrichtung einen piezoelektrischen oder piezoresistiven Drucksensor umfaßt.

30. Vorrichtung nach Anspruch 27, wobei die wenigstens eine Drucksensiervorrichtung nahe dem Niederdruckende des Axialverdichters angeordnet ist.

31. Vorrichtung nach Anspruch 27, wobei die Transformationseinheit eine schnelle Fourier-Tranformationseinheit umfaßt.

32. Vorrichtung nach Anspruch 27, wobei die Transformationseinheit eine schnelle Hartley-Tranformationseinheit (FHT) umfaßt.

33. Vorrichtung nach Anspruch 27, wobei eine Zustandsanzeigeeinheit vorgesehen ist zum Empfangen des Verschmutzungsparametersignals und zum Anzeigen desselben.

34. Vorrichtung zum Erfassen einer Verschmutzung eines Axialverdichters, wobei der Verdichter einen Rotor und ein Gehäuse umfaßt, wobei der Rotor drehbar innerhalb des Gehäuses zum Drehen um eine Drehachse mit variabler oder konstanter Drehgeschwindigkeit angebracht ist, wobei der Verdichter ferner wenigstens eine Verdichterstufe umfaßt, wobei jede der wenigstens einen Verdichterstufe eine Reihe von am Rotor angebrachten und aufeinander folgend in einer Umfangsrichtung bezüglich der Drehachse angeordneten Rotorschaufeln und eine Reihe von am Gehäuse angebrachten und aufeinander folgend in einer Umfangsrichtung bezüglich der Drehachse angeordneten Statorschaufeln aufweist, wobei die Vorrichtung umfaßt wenigstens eine Drucksensiervorrichtung zum Messen von Druckschwankungen innerhalb wenigstens einer der Verdichterstufen im Bereich des Gehäuses mittels wenigstens einer Drucksensiervorrichtung, wobei jede Drucksensiervorrichtung jeweils ein Sensorsignal ausgibt, wenigstens eine Transformationseinheit zum Ableiten eines Frequenzsignals von jedem der Sensorsignale, wobei das Frequenzsignal eine Gruppe einer Mehrzahl von Frequenzkomponenten von jedem der jeweiligen Sensorsignale in einem jeweiligen Frequenzintervall umfaßt, wobei jedes Frequenzsignal die Amplituden jeder der Frequenzkomponenten der jeweiligen Sensorsignale innerhalb des jeweiligen Freqeunzintervalls anzeigt, eine Integrationseinheit zum Integrieren des Frequenzsignals über ein vorbestimmtes Frequenzintervall und zum Ausgeben eines Integralwertsignals, eine Verschmutzungsparameter-Ableiteinheit zum Ableiten eines Verschmutzungsparametersignals vom Integralwertsignal.

35. Vorrichtung nach Anspruch 34, wobei die Drucksensiervorrichtung am Gehäuse zwischen den Rotorschaufeln und den Statorschaufeln von einem der Verdichterstufen angeordnet ist.

36. Vorrichtung nach Anspruch 34, wobei die Drucksensiervorrichtung einen piezoelektrischen oder piezoresistiven Drucksensor umfaßt.

37. Vorrichtung nach Anspruch 34, wobei die wenigstens eine Drucksensiervorrichtung nahe dem Niederdruckende des Axialverdichters angeordnet ist.

38. Vorrichtung nach Anspruch 34, wobei die Transformationseinheit eine schnelle Fourier-Transformationseinheit umfaßt.

39. Vorrichtung nach Anspruch 34, wobei die Transformationseinheit eine schnelle Hartley-Transformationseinheit (FHT) umfaßt.

40. Vorrichtung nach Anspruch 34, wobei eine Zustandsanzeigeeinheit vorgesehen ist zum Empfangen des Verschmutzungsparametersignals und zum Anzeigen desselben.

Revendications

1. Procédé de détection de l'encrassement d'un compresseur axial, ledit compresseur comprenant un rotor et un carter, ledit rotor étant monté, de manière à pouvoir tourner, à l'intérieur dudit carter, en rotation autour d'un axe de rotation à une vitesse de rotation variable ou constante, ledit compresseur comprenant en outre au moins un étage de compresseur, chacun desdits au moins un étage de compresseur comprenant une rangée d'ailettes de rotor montées sur ledit rotor et disposées successivement dans le sens circonférentiel par rapport audit axe de rotation, et une rangée d'ailettes de stator montées sur ledit carter et disposées successivement dans le sens circonférentiel par rapport audit axe de rotation, ledit procédé comprenant les étapes suivantes :

   a) la mesure des fluctuations de pression dans au moins un desdits étages de compresseur dans la zone dudit carter, au moyen d'au moins un dispositif de mesure de pression, chaque dispositif de mesure de pression fournissant, respectivement, un signal de capteur ;
   b) l'obtention d'un signal de fréquence à partir de chacun desdits signaux de capteur, ledit signal de fréquence comprenant un ensemble d'une pluralité de composantes de fréquence de chacun desdits signaux de capteur correspondants dans un intervalle de fréquence correspondant, dans lequel chaque signal de fréquence indique les amplitudes de chacune des composantes de fréquence desdits signaux de capteur correspondants à l'intérieur de l'intervalle de fréquence correspondant ;
   c) la vérification du fait qu'au moins une composante de fréquence dans au moins un desdits signaux de fréquence comprend en outre au moins un pic caractéristique dans une région de fréquence caractéristique attribuée à l'un desdits étages du compresseur, ladite fréquence caractéristique étant définie comme le produit de ladite vitesse de rotation et du nombre d'ailettes des ailettes de rotor de l'étage de compresseur correspondant ;
   d) l'obtention d'un paramètre d'encrassement à partir dudit signal de fréquence, ledit paramètre d'encrassement dépendant d'un paramètre de pic, ledit paramètre de pic indiquant la forme dudit pic caractéristique.

2. Procédé selon la revendication 1, dans lequel ledit dispositif de mesure de pression est placé au niveau dudit carter, entre les ailettes de rotor et les ailettes de stator de l'un desdits étages du compresseur.

3. Procédé selon la revendication 1, dans lequel ledit au moins un dispositif de mesure de pression est placé à proximité de l'extrémité de basse pression dudit compresseur axial.

4. Procédé selon la revendication 1, dans lequel ledit dispositif de mesure de pression comprend un capteur de pression piézoélectrique ou piézorésistif.

5. Procédé selon la revendication 1, dans lequel ledit signal de fréquence est obtenu par une transformation de Fourier rapide (TFR).

6. Procédé selon la revendication 1, dans lequel ledit signal de fréquence est obtenu par une transformation de Hartley rapide (THR).

7. Procédé selon la revendication 1, dans lequel ledit paramètre de pic indique la hauteur de pic du pic caractéristique.

8. Procédé selon la revendication 7, dans lequel la hauteur de pic est définie comme étant le rapport de la différence de la valeur maximale de l'ensemble de composantes de fréquence d'un signal de fréquence dans la région de ladite fréquence caractéristique et de la valeur moyenne dudit ensemble de composantes de fréquence dans une bande prédéterminée de fréquences autour de ladite fréquence caractéristique, à ladite valeur moyenne.

9. Procédé selon la revendication 1, dans lequel ledit paramètre de pic indique une largeur de pic dudit pic caractéristique.

10. Procédé selon la revendication 9, dans lequel ladite largeur de pic est définie comme étant la largeur complète à la moitié du maximum.

11. Procédé selon la revendication 1, dans lequel ledit intervalle prédéterminé de fréquence a une largeur inférieure à 4 000 Hz.

12. Procédé selon la revendication 11, dans lequel ledit intervalle prédéterminé de fréquence a une largeur de 2 000 Hz.

13. Procédé selon la revendication 1, dans lequel ledit paramètre d'encrassement est défini comme étant le paramètre de pic du pic caractéristique divisé par un paramètre de fonctionnement indiquant l'état de fonctionnement dudit compresseur.

14. Procédé selon la revendication 13, dans lequel ledit paramètre de fonctionnement indique la puissance de sortie du compresseur.

15. Procédé selon la revendication 1, dans lequel un

signal de changement d'état indiquant un changement de l'état de fonctionnement dudit compresseur est produit dans le cas où ledit paramètre d'encrassement a une valeur située en dehors d'une plage de valeur prédéterminée.

16. Procédé de détection de l'encrassement d'un compresseur axial, ledit compresseur comprenant un rotor et un carter, ledit rotor étant monté de manière à pouvoir tourner à l'intérieur dudit carter en rotation autour d'un axe de rotation à une vitesse de rotation variable ou constante, ledit compresseur comprenant en outre au moins un étage de compresseur, chacun desdits au moins un étages comprenant une rangée d'ailettes de rotor montées sur ledit rotor et disposées successivement dans le sens circonférentiel par rapport audit axe de rotation, et une rangée d'ailettes de stator montées sur ledit carter et disposées successivement dans le sens circonférentiel par rapport audit axe de rotation, ledit procédé comprenant les étapes suivantes :

a) la mesure des fluctuations de pression dans au moins un desdits étages de compresseur dans la zone dudit carter, au moyen d'au moins un dispositif de mesure de pression, chaque dispositif de mesure de pression fournissant, respectivement, un signal de capteur ;
b) l'obtention d'un signal de fréquence à partir de chacun desdits signaux de capteur, ledit signal de fréquence comprenant un ensemble d'une pluralité de composantes de fréquence de chacun desdits signaux de capteur correspondants dans un intervalle de fréquence correspondant dans lequel chaque signal de fréquence indique les amplitudes de chacune des composantes de fréquence desdits signaux de capteur correspondants à l'intérieur de l'intervalle de fréquence correspondant ;
c) l'obtention d'un paramètre d'encrassement à partir dudit signal de fréquence, ledit paramètre d'encrassement dépendant d'une valeur d'intégrale dudit signal de fréquence, ladite valeur d'intégrale étant définie comme étant l'intégrale dudit signal de fréquence sur un intervalle prédéterminé de fréquence.

17. Procédé selon la revendication 16, dans lequel ledit dispositif de mesure de pression est placé au niveau dudit carter, entre les ailettes de rotor et les ailettes de stator de l'un desdits étages du compresseur.

18. Procédé selon la revendication 16, dans lequel ledit au moins un dispositif de mesure de pression est placé à proximité de l'extrémité de basse pression dudit compresseur axial.

19. Procédé selon la revendication 16, dans lequel ledit dispositif de mesure de pression comprend un capteur de pression piézoélectrique ou piézorésistif.

20. Procédé selon la revendication 16, dans lequel ledit signal de fréquence est obtenu par une transformation de Fourier rapide (TFR).

21. Procédé selon la revendication 16, dans lequel ledit signal de fréquence est obtenu par une transformation de Hartley rapide (THR).

22. Procédé selon la revendication 16, dans lequel ledit intervalle d'intégration est compris entre 0 et 20 000 Hz.

23. Procédé selon la revendication 16, dans lequel ledit intervalle de fréquence est égal audit intervalle d'intégration.

24. Procédé selon la revendication 16, dans lequel ledit paramètre d'encrassement est défini comme étant la valeur d'intégrale divisée par un paramètre de fonctionnement, indiquant l'état de fonctionnement.

25. Procédé selon la revendication 24, dans lequel ledit paramètre de fonctionnement indique la puissance de sortie du compresseur.

26. Procédé selon la revendication 16, dans lequel un signal de changement d'état indiquant un changement de l'état de fonctionnement dudit compresseur est produit dans le cas où ledit paramètre d'encrassement a une valeur située en dehors d'une plage de valeur prédéterminée.

27. Dispositif de détection de l'encrassement d'un compresseur axial, ledit compresseur comprenant un rotor et un carter, ledit rotor étant monté de manière à pouvoir tourner à l'intérieur dudit carter en rotation autour d'un axe de rotation à une vitesse de rotation variable ou constante, ledit compresseur comprenant en outre au moins un étage de compresseur, chacun desdits au moins un étages comprenant une rangée d'ailettes de rotor montées sur ledit rotor et disposées successivement dans le sens circonférentiel par rapport audit axe de rotation, et une rangée d'ailettes de stator montées sur ledit carter et disposées successivement dans le sens circonférentiel par rapport audit axe de rotation, ledit dispositif comprenant au moins un dispositif de mesure de pression pour mesurer les fluctuations de pression dans au moins un desdits étages de compresseur dans la zone dudit carter au moyen d'au moins un dispositif de mesure de pression, chaque dispositif de mesure de pression fournissant un signal de capteur, respectivement, à au moins une unité de transformation pour obtenir un signal de

fréquence à partir de chacun desdits signaux de capteur, ledit signal de fréquence comprenant un ensemble d'une pluralité de composantes de fréquence de chacun desdits signaux de capteur correspondants dans un intervalle de fréquence correspondant dans lequel chaque signal de fréquence indique les amplitudes de chacune des composantes de fréquence desdits signaux de capteur correspondants à l'intérieur de l'intervalle de fréquence correspondant, une unité d'évaluation de pic destinée à vérifier si au moins une composante de fréquence dans au moins un desdits signaux de fréquence comprend en outre un pic caractéristique dans la région de fréquence caractéristique attribuée à l'un desdits étages de compresseur, ladite fréquence caractéristique étant définie comme le produit de ladite vitesse de rotation et du nombre d'ailettes des ailettes de rotor de l'étage de compresseur correspondant, une unité d'obtention de paramètre d'encrassement pour l'obtention d'un paramètre d'encrassement à partir dudit signal de fréquence, ledit paramètre d'encrassement dépendant d'un paramètre de pic, ledit paramètre de pic indiquant la forme dudit pic caractéristique.

28. Dispositif selon la revendication 27, dans lequel ledit dispositif de mesure de pression est placé au niveau dudit carter, entre les ailettes de rotor et les ailettes de stator de l'un desdits étages du compresseur.

29. Dispositif selon la revendication 27, dans lequel ledit dispositif de mesure de pression comprend un capteur de pression piézoélectrique ou piézorésistif.

30. Dispositif selon la revendication 27, dans lequel ledit au moins un dispositif de mesure de pression est placé à proximité de l'extrémité de basse pression dudit compresseur axial.

31. Dispositif selon la revendication 27, dans lequel ladite unité de transformation comprend une unité de transformation de Fourier rapide.

32. Dispositif selon la revendication 27, dans lequel ladite unité de transformation comprend une unité de transformation de Hartley rapide (THR).

33. Dispositif selon la revendication 27, dans lequel une unité indicatrice d'état est utilisée pour recevoir ledit paramètre d'encrassement et indiquer celui-ci.

34. Dispositif de détection de l'encrassement d'un compresseur axial, ledit compresseur comprenant un rotor et un carter, ledit rotor étant monté de manière à pouvoir tourner à l'intérieur dudit carter en rotation autour d'un axe de rotation à une vitesse de rotation variable ou constante, ledit compresseur comprenant en outre au moins un étage de compresseur, chacun desdits au moins un étages comprenant une rangée d'ailettes de rotor montées sur ledit rotor et disposées successivement dans le sens circonférentiel par rapport audit axe de rotation, et une rangée d'ailettes de stator montées sur ledit carter et disposées successivement dans le sens circonférentiel par rapport audit axe de rotation, ledit dispositif comprenant au moins un dispositif de mesure de pression pour mesurer les fluctuations de pression dans au moins un desdits étages de compresseur dans la zone dudit carter au moyen d'au moins un dispositif de mesure de pression, chaque dispositif de mesure de pression fournissant un signal de capteur, respectivement, à au moins une unité de transformation pour obtenir un signal de fréquence à partir de chacun desdits signaux de capteur, ledit signal de fréquence comprenant un ensemble d'une pluralité de composantes de fréquence de chacun desdits signaux de capteur correspondants dans un intervalle de fréquence correspondant dans lequel chaque signal de fréquence indique les amplitudes de chacune des composantes de fréquence desdits signaux de capteur correspondants à l'intérieur de l'intervalle de fréquence correspondant, une unité d'intégration pour intégrer ledit signal de fréquence sur un intervalle prédéterminé de fréquence et pour produire un signal de valeur d'intégrale, une unité d'obtention de paramètre d'encrassement pour obtenir un signal de paramètre d'encrassement à partir dudit signal de valeur d'intégrale.

35. Dispositif selon la revendication 34, dans lequel ledit dispositif de mesure de pression est placé au niveau dudit carter, entre les ailettes de rotor et les ailettes de stator de l'un desdits étages du compresseur.

36. Dispositif selon la revendication 34, dans lequel ledit dispositif de mesure de pression comprend un capteur de pression piézoélectrique ou piézorésistif.

37. Dispositif selon la revendication 34, dans lequel ledit au moins un dispositif de mesure de pression est placé à proximité de l'extrémité de basse pression dudit compresseur axial.

38. Dispositif selon la revendication 34, dans lequel ladite unité de transformation comprend une unité de transformation de Fourier rapide.

39. Dispositif selon la revendication 34, dans lequel ladite unité de transformation comprend une unité de transformation de Hartley rapide (THR).

40. Dispositif selon la revendication 34, dans lequel une unité indicatrice d'état est utilisée pour recevoir ledit signal de paramètre d'encrassement et indiquer celui-ci.

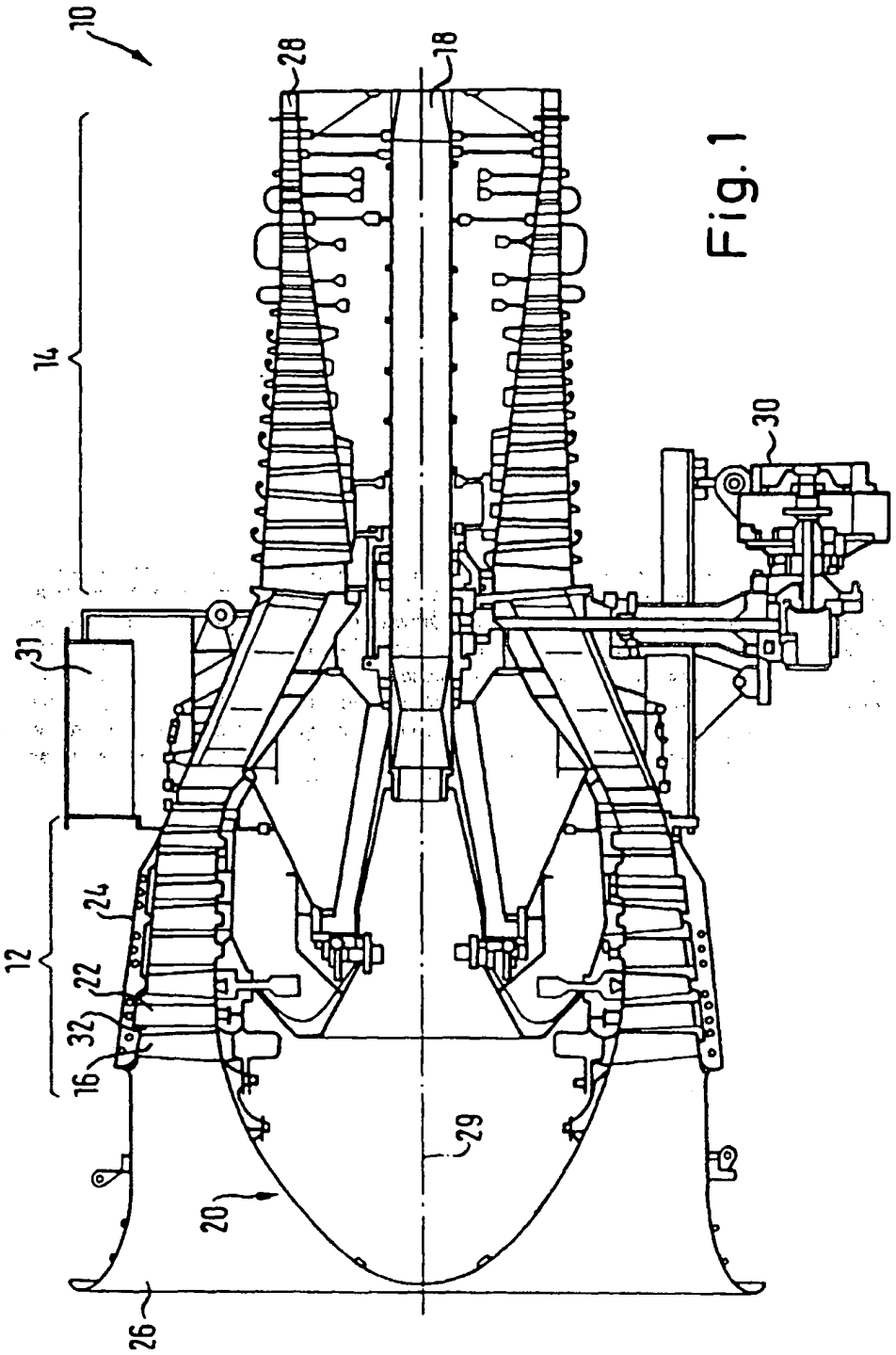


Fig. 1

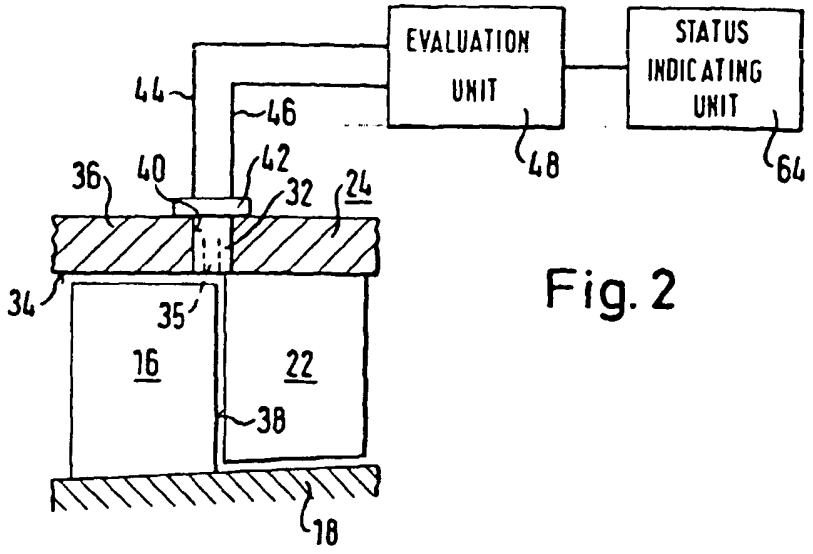

EVALUATION UNIT
STATUS INDICATING UNIT
44
46
48
64
36
40
42
32
24
34
35
16
22
38
18

Fig. 2

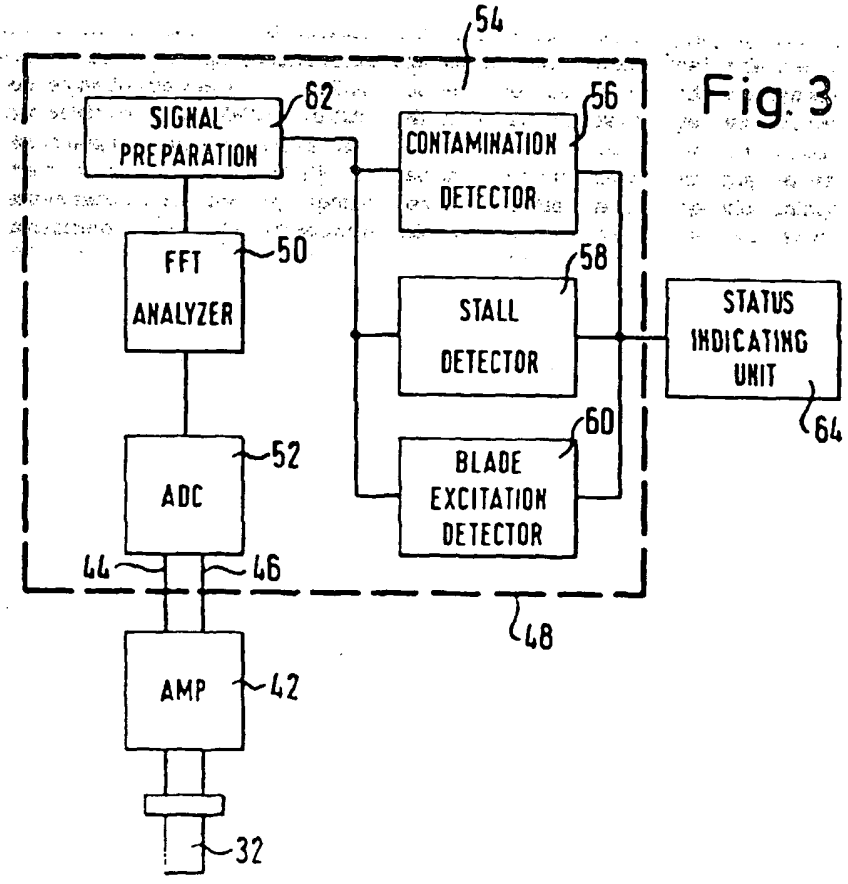

54
SIGNAL PREPARATION
62
CONTAMINATION DETECTOR
56
FFT ANALYZER
50
STALL DETECTOR
58
STATUS INDICATING UNIT
64
ADC
52
BLADE EXCITATION DETECTOR
60
44
46
48
AMP
42
32

Fig. 3

Fig. 4

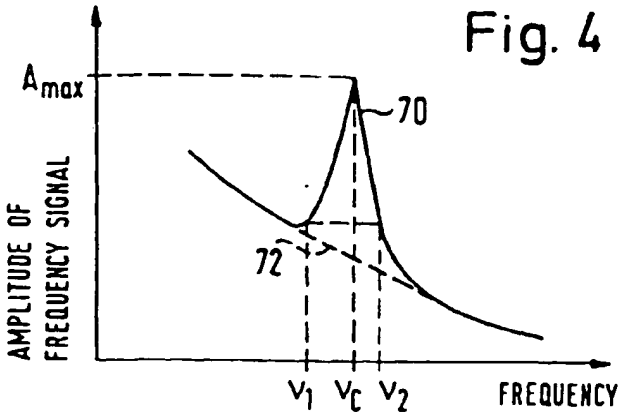


Fig. 5a

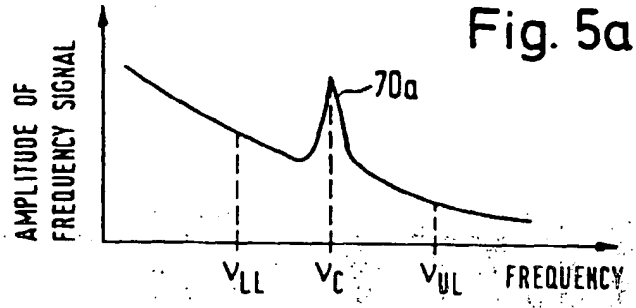


Fig. 5b

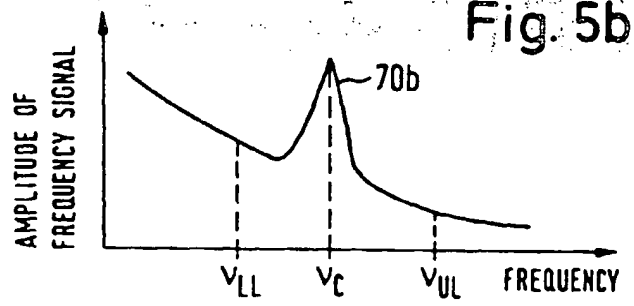


Fig. 5c

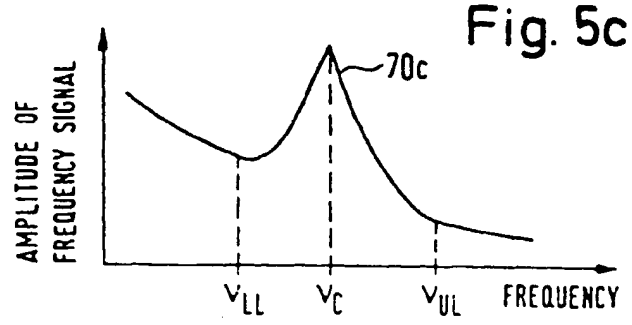


Fig. 6

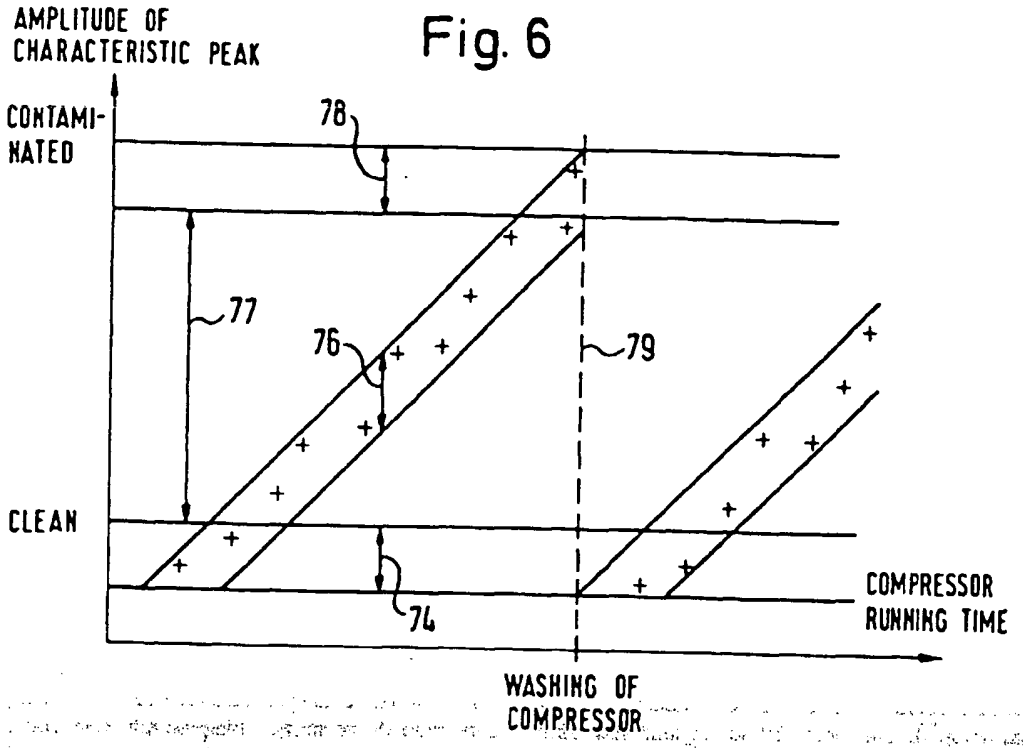

AMPLITUDE OF CHARACTERISTIC PEAK
CONTAMI-NATED
78
77
76
79
CLEAN
74
COMPRESSOR RUNNING TIME
WASHING OF COMPRESSOR

Fig. 7

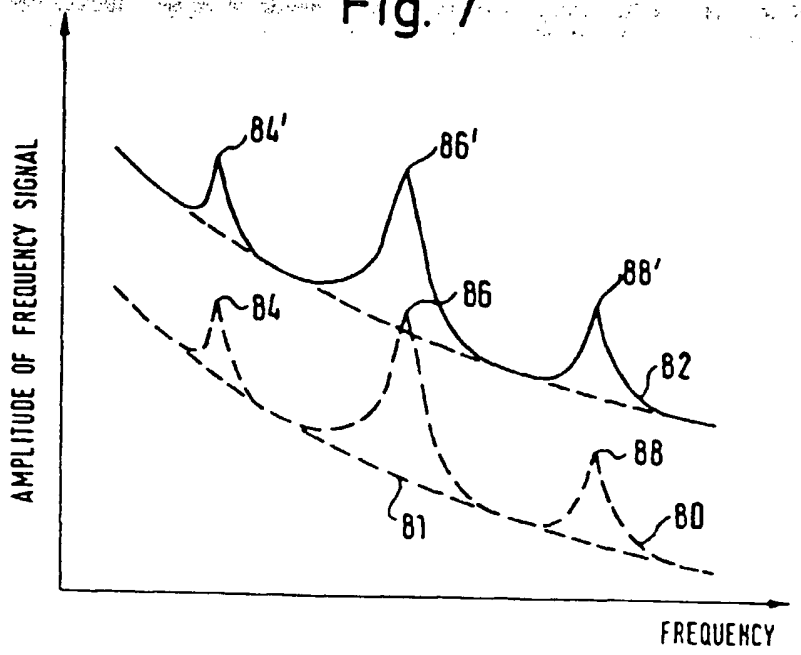
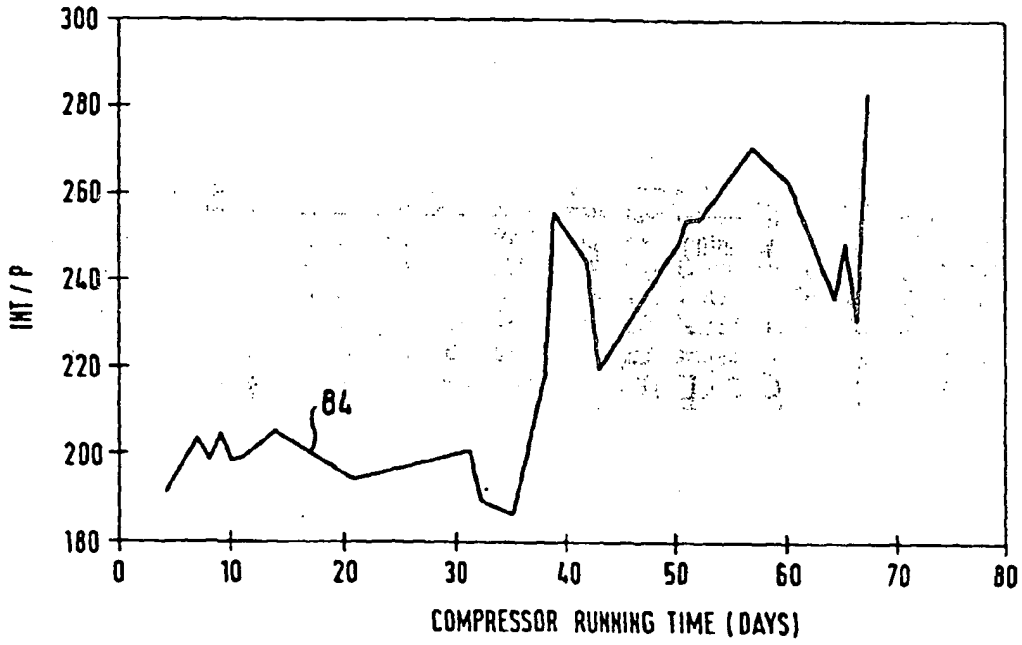

AMPLITUDE OF FREQUENCY SIGNAL
84'
86'
88'
84
86
82
88
81
80
FREQUENCY

Fig. 8


300
280
260
240
220
200
180
INT / P
84
0
10
20
30
40
50
60
70
80
COMPRESSOR RUNNING TIME (DAYS)

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